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Consumer Product Innovation and Sustainable Design – Robin Roy

Robin Roy

Emeritus Professor of Design and Environment

The Open University, Design Group, Department of Engineering and Innovation

Faculty of Mathematics, Computing and Technology, Walton Hall

Milton Keynes MK7 6AA

United Kingdom

Introduction

This paper summarises some findings of a book titled *Consumer Product Innovation and Sustainable Design* (Roy, 2016). The book is based on the author's previous research (e.g. Roy 1994, Roy 1997, Roy 2006, Roy and Tovey 2012) and was inspired by his archive of the (UK) Consumers' Association publication, *Which?* that provides a unique written and pictorial record of the technological and design evolution of consumer products marketed in Britain from 1957 to the present. To produce its reports on consumer durables the Consumers' Association buys products and employs a variety of methods to evaluate them, including laboratory tests, expert evaluations and consumer trials. Conclusions on which products consumers are recommended to buy, based on their price, specification and the performance evaluations, are provided in *Which?* magazine and also online.

The core of the book comprises case studies of six consumer product classes – bicycles, washing machines, electric lamps, television equipment, vacuum cleaners and mobile (cell) phones. The case studies draw upon the reports in *Which?* plus numerous other print and online sources to track the technological and design evolution of these products from their invention to the present day.

Given the range of consumer products *Which?* reports on, it was necessary to choose which to focus on. The chosen six product classes listed above was based on selecting for different levels of technological complexity, rates of technological and design change and the relative importance of engineering, aesthetic, human and environmental factors in design. The case studies then examined when, why and how environmental criteria became part of their specification; the influence of socio-economic and cultural factors on their evolution; and their impacts on the environment and society.

There is not space to provide the details of the case studies. Instead the paper draws on them to provide conclusions about patterns of technological and design change and to provide lessons for designers, engineers, managers, marketers and educators – for example, on what makes some consumer products successful and others market failures, and how to design for sustainability.

Patterns of innovation

The first conclusion is that the different product classes follow similar patterns of evolution; going through one or more divergent, convergent and divergent phases.

For all the products, one or more key inventions were created, such as Edison's carbon filament electric lamp, which started an initial divergent phase of design experimentation and technical development. Early designs often look like an assembly of functional parts, which become increasingly integrated as the parts are enclosed and the product is designed as a whole. This phase is typically driven by the attempts by inventors, designers, engineers and manufacturers to eliminate the deficiencies of existing designs and produce more practical and desirable products. Utterback and Abernathy (1975) described this as the 'Fluid Phase' of innovation.

Following this experimental phase, one or more 'dominant designs' typically emerge – as originally proposed by Utterback and Abernathy (1975). The dominant design(s) converge on one or more standard technologies and configurations; for example conventional upright and cylinder suction vacuum cleaners. The efforts of designers, engineers and manufacturers focus on making incremental product improvements and stylistic changes and on introducing new or improved components, materials and production processes. The changes in this phase are driven by continued attempts to eliminate the shortcomings of existing designs, to reduce production costs and respond to customer

feedback and changing fashions. Manufacturers typically also create product ranges for different market segments and may start designing to reduce environmental impacts.

The dominant design phase is usually followed by another period of technological divergence and design variety. This phase arises because inventors, designers, engineers, manufacturers and new entrants to the market start to apply new product or process technologies, materials and components to create radically new products and so-called 'disruptive' innovations (Utterback, 1994; Christensen, 2000), such as Dyson's cyclonic vacuum cleaner [Figure 1].



Figure 1 James Dyson's G-Force cleaner, 1986; the first cyclonic vacuum cleaner made and sold in Japan led to the disruptive innovation of the 1993 UK-made Dyson DC01 (R. Roy)

An important driver for the development of these innovative products is to cope with stagnating or saturated consumer demand. Innovation is also required to fend off competition from low cost manufacturers, to generate new consumer wants, and to meet environmental and safety legislation or standards. The technological competition seen in the early experimental phase of product innovation reappears in this second divergent phase. Existing dominant designs may survive for a long time alongside the innovative products, as incandescent light bulbs did in competition with compact fluorescent lamps, or may disappear, as analogue mobile phones and television did when digital phones and television systems were introduced.

Although the above sections reveal patterns of divergence, convergence and divergence for all the case study products, there are differences in the rates of change depending on the technologies on which the products are based. Washing machines, an electro-mechanical product, are still in an early second divergent phase with the established top- and front-loading designs still dominant. Electric lighting has been in a divergent phase for decades with fluorescent technologies challenging the old dominant designs of incandescent lamp and is beginning to converge again towards a new dominant design – solid state LEDs (Figure 2). The electronic products, television and mobile phones, have already passed through at least two divergent and convergent phases and are entering another divergent stage, for example with flexible-screen designs under development.

For business strategists, product planners, designers and marketers, therefore, understanding patterns of innovation is important; because by knowing where their products are located in the evolution of their industry, they should be better able to anticipate change, exploit new opportunities and avoid being overtaken by competitors or disruptive innovations.

Designing for product success

Many new products and innovations fail to diffuse into widespread use, while others have become highly successful in terms of adoption and/or profitability. What do the case studies indicate distinguishes these successful products and innovations from the less successful ones?

Genuine innovation

For a genuine innovation or 'first to the world' product to succeed it must offer a function or other benefit that previously did not exist and that consumers need or want. Here are some examples from the case studies:

LED lamps (Figure 2) offer improved efficiency, compactness, cooler operation and lower running costs than compact fluorescent and halogen incandescent lamps and so are gradually displacing these earlier technologies.



Figure 2 Solid-state light emitting diode (LED) lamps for general lighting, an early 21st Century innovation now becoming a new dominant design (R. Roy)

Digital television offered multiple channels and better pictures and sound than analogue TV. Subsequently flat panel technologies provided much larger screen, slimmer digital TVs with even better picture quality, while using much less energy than previous CRT designs. The first iPhone of 2007 offered many advantages over other smartphones, including ease of use, touchscreen icons and keyboard, a number of apps and a desirable design. To compete other manufacturers had to develop their own touchscreen smartphones based on the concepts pioneered by the iconic iPhone.

Relative advantage

Very few new products are 'first to the world' innovations, and so must compete with established products. To succeed such new products must offer what consumers consider to be a genuine advantages over rival products or systems; what Rogers (1995) calls 'relative advantage'. For example, Sony's Trinitron colour TV tube offered better picture quality than conventional colour CRTs, and so made Sony TVs very successful in the 1970s (Figure 3a). Conversely, the LaserDisc (Figure 3b), a high definition rival to video-recorders launched in the 1980s failed the test of relative advantage. The player and discs were more expensive, could not be recorded on, and could only store a shorter recording than video-recorders and videocassettes. For consumers, all these disadvantages outweighed the LaserDisc's higher definition pictures.



Figure 3 (a) Sony Trinitron colour cathode ray tube TV (c. 1970), a successful innovation, mainly due to its better picture quality (R. Skitmore, Creative Commons) (b) Philips LaserDisc player (1982) failed to catch on because of its higher price and perceived lack of relative advantage over video-cassette recorders (R. Roy)

Thus, to be adopted in preference to competing products, manufacturers must develop products that offer relative advantages; especially an equal or higher specification and a better functional performance than rival products at a competitive price. They should of course focus on other factors influencing consumer choice, including brand image and emotional appeal.

Good design

In the early experimental phase of innovation, products are often designed as assemblies of functional components with little attention paid to their ease of use, form and user interfaces. As the products evolve, increasing effort is normally devoted to their industrial and ergonomic design in order to make them more useable, visually appealing and fashionable.

Electric washing machines are an example of a product that started as an assembly of functional parts – wooden tub, external motor, drive belts, wringer, etc. As they evolved the parts became more integrated; first with the mechanical parts enclosed, then with the cabinet design changing from round tubs on legs reminiscent of earlier machines to box shapes. With the automatic washing machine the drying mechanism was integrated into the cabinet. With further evolution washing machine controls became more sophisticated and so attention was paid to user interface design, informative displays

and energy efficiency. The latest machines are increasingly sleek in form with large glass portholes and electronic displays to echo contemporary product and kitchen aesthetics (Figure 4).



Figure 4 Samsung Ecobubble™ washing machines mix detergent with water and air so the detergent will penetrate laundry efficiently, thus reducing detergent, water and energy use. Performance tested by Which? in 2014 and selected as a 'Best Buy'. (R. Roy)

Affordable price

When first introduced new products and innovations command premium prices, and so are mainly adopted by wealthy consumers and enthusiasts. Then, with improved scale of production, and in order to expand the market, manufacturers reduce prices. If its unique functions or relative advantages are considered by consumers to represent 'value for money', many more will adopt the innovation.

For example, when first introduced in Britain in 1967 a colour TV cost about £300 (about £4750 today) so most people rented. Six years later the price had almost halved, sets such as Sony's Trinitron TV (Figure 3a) had become reliable, so it became worthwhile to buy (Consumers' Association 1972). Today you can pay from £150 to nearly £3000 for a high definition TV. However, the technology, product platforms and many components are common to the different models. Thus TVs have become affordable for almost everyone in industrialised countries, with upmarket models available at premium prices for those who can afford them.

System compatibility

Many consumer products have to interface with other products and systems, so compatibility with these other technologies is essential. To diffuse widely the products have also to be compatible with consumer requirements and preferences and meet any prevailing national or international standards and legislation. Thus, the success of the first digital mobile phones was facilitated by the EU's agreement to adopt GSM digital technology, which became the standard most widely adopted outside the USA.

The importance of system interdependency has been highlighted by Shove (2003). She argues, for example, that clothes laundering should be viewed as a 'system of systems' in which washing machine manufacturers have to design their products taking into account the actions of detergent manufacturers, textile producers and users. This means that washing machines designed for different markets need to provide wash programmes that suit the detergent formulations, clothing and laundry habits of consumers in different countries and climates.

Designing for the environment

So far environmental performance has only been mentioned in passing as a factor in the success of consumer products. However, it is clear from the case studies that designing for the environment (DfE) has become increasingly important. Brezet (1997) proposed four levels of DfE; which have subsequently been termed (e.g. by Roy, 2006) as green design; ecodesign; sustainable design; and sustainable innovation.

Green design

Green design is the approach most manufacturers adopt when they begin to address product environmental impacts, focusing on the impacts necessary to satisfy legislation or are easy to achieve even if they are not the most significant.

For example, addressing the main energy and resource impacts of television did not become a major factor in equipment design until the early 21st Century. But before that there was great concern about the relatively smaller use of electricity when TV equipment was left on standby. This stimulated regulatory actions, such as the 1999 International Energy Agency's *1 Watt Initiative*, which led to the average new TV's standby consumption falling from about 5 watts to 1 watt or less.

Ecodesign

Ecodesign, or life-cycle design, the next level of DfE, attempts to assess environmental impacts throughout a product's life cycle in order to focus on the most important impacts.

An important stimulus for manufacturers, especially of energy-using products, to shift from green design to eco-design has been environmental policies and regulation. These include the US 1992 voluntary Energy Star program, the EU's 2003 *Integrated Product Policy*, the 2009 *Ecodesign for Energy-related Products Directive* and Directives on Energy Labelling of products.

The EU Ecolabel for washing machines, for example, rested on a life cycle analysis (LCA) study that demonstrated that over 90% of the machines' environmental impacts occurred at the use phase (Durrant et al 1991). This determined that the main Ecolabel criteria for washing machines should be low energy, water and detergent consumption. This stimulated Hoover (UK) to design its New Wave range of washing machines; awarded the first Ecolabel in 1993. LCA studies of mobile phones carried out by different manufacturers indicated that the impacts of their products varied widely, but were concentrated on the materials extraction, component manufacture and use life cycle phases. Hence different manufacturers focussed their efforts on different measures; from Apple auditing its Far Eastern factories to ensure pollution compliance to Nokia (before it was taken over by Microsoft) designing energy efficient phone chargers.

A drawback of LCA-based eco-design is that it is complex, expensive and often difficult to translate into designs. Most companies therefore employ methods based on life cycle *thinking*, rather than LCA studies. At Philips, for example, product development teams are expected to focus on one or more Green Focal Areas – Energy efficiency; Packaging; Substances; Weight; Recycling and disposal; Lifetime reliability (Philips 2014). Philips has found that using the Green Focal Areas checklist helps to identify the most important impacts of products. For example, Philips Lighting found that as well as energy efficiency, product life is important because durability also saves materials.

Sustainable design

Sustainable design aims to provide the essential function of a product using the least environmentally harmful technical solution, for example, using solar power instead of grid electricity or batteries. Sustainable design also includes socio-economic considerations, such as a product's fair trade implications or workplace health and safety.

An example of attempts to implement sustainable design concerns smartphones. In moving from eco-design to sustainable design, Microsoft and Apple now attempt to reduce smartphone energy and resource use by incorporating power-saving software, minimising materials use, and eliminating more harmful substances than is required by legislation. They have also been persuaded (e.g. by pressure groups such as the Gaia Foundation – Figure 5) to consider materials sources and factory conditions, for example to avoid child labour and 'conflict minerals' such as tantalum, tungsten and gold, which may be mined by slave labour and traded under the control of violent armed groups.

A more radical response has been an 'ethical' smartphone, called Fairphone, specifically designed to avoid use of conflict minerals developed by a Dutch social enterprise. Among its other requirements, the Fairphone was designed to be repairable to extend its useful life, recyclable and manufactured in Chinese factories with fair pay and good working conditions. It was funded via pre-orders from the public with about 50,000 phones sold by 2014 (Fairphone, 2014).



Figure 5 Spoof advertisement highlighting the negative impacts involved in mining materials for mobile phones. The 'apps' on this phone are: resource depletion, ecosystem destruction, land grabbing, inbuilt obsolescence, toxic waste, conflict minerals, poor working conditions (Courtesy of The Gaia Foundation www.gaiafoundation.org)

Sustainable innovation

Sustainable innovation is even broader in scope than sustainable design and goes beyond technical solutions. Sustainable innovation involves providing a particular function using environmentally optimal product-service mixes or socio-technical systems. It also requires developers to take into account the socio-economic sustainability of any proposed new product-service or system. For example, innovations that could provide a more sustainable system for providing clean clothes might include: innovative washing machines (e.g. polymer bead washers that use minimal water and detergent); laundries equipped with environmentally efficient technologies (e.g. heat recovery and water recycling); and a clothes-sharing service.

The rebound effect

The above DfE approaches largely ignore the potentially negative environmental effects of consumer behaviour and social changes. For example, consumers may choose to buy larger products, which use more resources and energy; or they may buy several products instead of one. Social changes, such as the increasing number of single person households also increases the amounts of domestic equipment bought and used. Consumers, for example, are choosing large screen, smart TVs that use more energy than smaller, non-smart models and to own several sets per household. Some consumers have installed additional lighting in their homes and tend to leave lights on longer after fitting low energy light bulbs (Herring and Sorrell, 2008).

Measures to address the rebound effect include designing products with economy or energy-saving settings or to mitigate the impacts of increased consumption, products can be designed for repair or upgrading (e.g. the Phonebloks (2015) modular smartphone) and/or for reuse or recycling. A few businesses have developed products for the increasing number of single-person households.

Socio-economic and cultural influences and impacts

As well as considering the rebound effect, inventors, engineers, designers and manufacturers need to understand that new products and innovations are not the result of inevitable technological progress, human creativity or market forces. Social, political, commercial and cultural factors influence, or determine, which new products and innovations are created, introduced and adopted. Thus, Burns (1998) describes how the historical development of television was not simply the result of a series of scientific and technological innovations. Its evolution was shaped by government controls on broadcasting frequencies, international rivalries on broadcast standards, patent disputes, the dedication of engineering teams in companies like RCA and EMI, and many other non-technical factors.

Shove (2003) furthermore argues that people's behaviour in the use of products is strongly influenced by changing conceptions of what is 'normal', itself shaped by powerful cultural and technical forces. For example, with post-War cultural shifts in Western society towards higher standards of cleanliness, and as more textiles became machine washable, clothes began to be washed more frequently. Together with spread of automatic washing machines, this has increased the weekly to an almost daily wash in industrialised countries.

Hence, although inventors, designers and engineers cannot control social, cultural and political forces, it is important that they appreciate that these forces affect innovation and so need to consider the wider context in which they are attempting to innovate.

Sustainable design and innovation

As noted above, designing for the environment is an important socio-economic and cultural force, not just for the planet, but to satisfy a growing proportion of people and for profit too. Thus, all major manufacturers of consumer durables now have detailed environmental and sustainability policies and action plans.

Designing for the environment is evolving from narrow green design approaches to designing more sustainable product-service mixes and socio-technical systems. Many examples of the latter sustainable approaches are now emerging. It is possible to lease LED lighting as a service package, thus overcoming the upfront cost of an efficient lighting system. And there are trials of services that provide clothes for rent or loan, which also wash, clean, iron and repair them.

The shift to sustainable design and innovation is of growing urgency as ownership of consumer products spreads from industrialised countries, first to newly industrialised countries such as China, and India and then, with increased electrification, to low income countries. For example, over two billion people already own a washing machine and an estimated further three billion in developing countries will want one by 2050 (Rosling 2010). The level of smartphone ownership in China already exceeds that in Britain. In the future global ownership of such products seems likely to approach saturation, which combined with the expected increase in population to 9.6 billion by 2050, will produce unsustainable emissions and pollution levels and pressure on natural resources unless future products, services and systems are designed for sustainability.

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